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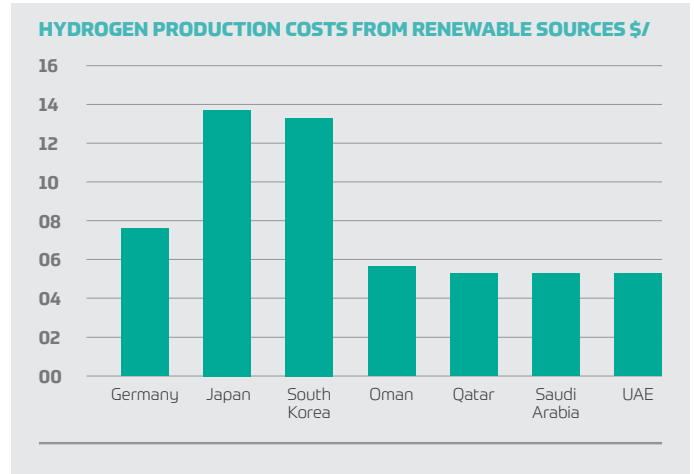
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PROGRESS ON THE PATH TO MIDDLE EAST HYDROGEN EXPORTS

Attention for the nascent low-carbon hydrogen industry reached new heights in 2022 around the world, with the Middle East being no exception. Several countries in the region issued low-carbon hydrogen roadmaps and targets, and there was a flurry of new announcements for large-scale projects. New projects emerged for both green hydrogen, produced via water electrolysis using renewable power, and its blue counterpart, made from natural gas with carbon capture and storage or use. Most of these projects have set their sights firmly on exports to markets where producing hydrogen and its derivatives could be considerably more expensive. Announcements in 2022 underlined that three countries are eyeing potential imports from the Middle East particularly keenly: Germany, Japan and South Korea.

The three countries are expected to be key importers of hydrogen because of their strong demand for industrial processes and limited domestic production potential. Production of hydrogen from renewable sources in South Korea and Japan is among the most expensive in the world, Argus calculations show, highlighting the countries' likely reliance on imports to limit the costs of a transition into a decarbonised future. Argus calculates prevailing costs for producing hydrogen from dedicated renewable installations using a 100MW proton exchange membrane (PEM) electrolyser at nearly \$13/kg for South Korea and \$13.80/kg for Japan, including capital expenditure. This is more than double the cost of equivalent production in Middle Eastern countries, which Argus calculates



at under \$6/kg. Renewable hydrogen production in Germany may be less costly than in South Korea and Japan, but the country will also likely be heavily reliant on imports to meet its domestic hydrogen demand in the future. The Middle East could present an economically viable source of low-carbon hydrogen imports for Germany, thanks to its relative proximity to Europe compared with other potential major exporters, such as southern Africa and South America.

In the following, Argus highlights key recent developments on the path to establishing low-carbon hydrogen supply chains between the Middle East and the three countries.



SOUTH KOREA



South Korean companies have been particularly active in recent months in forging collaborations to secure low-carbon hydrogen and derived products from the Middle East. Seoul foresees a key role for hydrogen and ammonia not only in power generation and industrial processes, but — arguably more so than most other countries — also in road transport.

South Korean chemical producer Lotte Fine Chemical's (LFC) deals for blue ammonia imports from Saudi Arabian chemical manufacturers Sabic, a subsidiary of state-controlled Saudi Aramco, and Saudi Arabian mining company Ma'aden received particular attention recently — because of LFC's statements



Kogas 2030 target for “overseas green hydrogen production and import”

that the agreements constituted the world's first commercial contracts for clean ammonia certified by Germany-based industrial accreditation provider TUV Rheinland. LFC in late October signed contracts for the delivery of 25,000t of ammonia from each of the two companies by the end of the year, with the supply to be shipped to the South Korean company's ammonia terminal at Ulsan port. The supply contracts are expected to help establish specific certification standards as South Korea's trade, industry and energy ministry aims to introduce a hydrogen certification system by 2024.

Other South Korean firms are looking to get involved more directly in Middle Eastern production projects. A group of five South Korean firms — comprising state-owned utilities Kepco and Korea Southern power, state-owned oil firm KNOC, conglomerate Samsung C&T and steel producer Posco — in November struck a deal with Saudi Arabia's sovereign Public Investment Fund to co-operate on hydrogen and ammonia production in Saudi Arabia. The plans involve the development of a green hydrogen and ammonia project with a 1.2mn t/yr production capacity, although the firms did not provide a breakdown of the output of the two products.

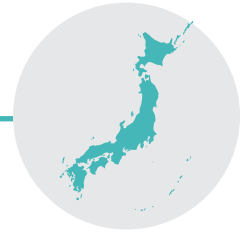
According to Kepco, South Korea will need to secure more than 80pc of domestic hydrogen and ammonia demand overseas, and the company's efforts in the Middle East have not been restricted to Saudi Arabia. Kepco, Samsung C&T and utility Korea Western Power in June reached an agreement with UAE-based Petrolyn Chemie to jointly develop a renewable hydrogen and ammonia production plant in the Khalifa Industrial Zone in Abu Dhabi.

State-owned gas firm Kogas also has ambitious plans for hydrogen imports, having in late October revised its 2030 target for “overseas green hydrogen production and import” to up to 1mn t/yr, from 200,000 t/yr under a previous plan in September 2021. The company has identified the Middle East — alongside Australia — as a key focus area for hydrogen imports.

South Korea has shown openness to both blue and green hydrogen and is also pursuing multiple routes with regard to potential transport vectors for imports. Seoul's national hydrogen roadmap from early November specified that the company would seek to build a 4mn t/yr ammonia import terminal in the coming years but that it would also aim to construct a separate complex that could receive 100,000 t/yr of liquid hydrogen.



JAPAN



Low-carbon hydrogen imports play a key role in Japan's decarbonisation strategy as well, with a particular focus on the potential for ammonia co-firing to reduce fossil fuel consumption for power generation.

Supply from the Middle East could play a crucial role in this endeavour. According to a task force formed by Japan's trade and industry ministry, the Middle East could provide blue ammonia at lower costs to Japan than any other region in the world, even undercutting other promising exporting locations. The task force estimates that Japan could import blue ammonia on a cost-and-freight basis for \$335-339/t from the Middle East by 2030, below estimated costs of \$413/t from North America and \$429/t from Australasia.

 **\$335-339/T**

blue ammonia on a cost-and-freight basis from the Middle East by 2030

Japan had in 2020 already received what Aramco said was the world's first shipment of blue ammonia and Japanese firms have since sought to secure further low-carbon supply from the Middle East. Most recently, Japanese engineering firm IHI and Dubai's state-owned Enoc said that they would explore

producing green ammonia from solar power at existing oil terminals owned by Enoc's subsidiary Horizon Terminals. Both companies aim to launch operations by 2028 and target 200,000 t/yr of capacity. Existing LPG tanks at the terminals could be repurposed to export ammonia, the firms said.

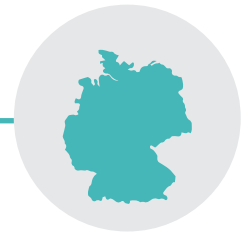
Japan's state-controlled energy agency Jogmec has signed an initial agreement with Aramco, with a view to connect the Japanese private sector with the Saudi firm. The intention is to facilitate the use of hydrogen and ammonia for power generation and as marine fuels, Jogmec said.

Earlier this year, Japanese refiner Cosmo Oil agreed to buy a blue ammonia cargo from Adnoc, following an agreement between the companies in March to jointly explore decarbonisation technologies.

But hydrogen may also be supplied to Japan from the Middle East without converting it into ammonia. Japanese refiner Eneos and compatriot trading house Mitsui in June struck a deal with Abu Dhabi's state-owned Adnoc to transport blue hydrogen from the UAE to Japan using methylcyclohexane (MCH) as a liquid organic hydrogen carrier (LOHC). Eneos sees MCH as key to transporting hydrogen to Japan, as it can be shipped and stored in the same way as crude and oil products, using existing infrastructure such as storage tanks, pipelines and tankers. Japanese engineering company Chiyoda, is one of the global trailblazers in the development of MCH and LOHC, which could open up opportunities for using these technologies to ship hydrogen from the Middle East to Japan.



GERMANY



Germany has arguably been among the countries hit hardest by the energy crisis that developed in the aftermath of Russia's conflict in Ukraine, because it has for decades relied heavily on Russian gas for heating, power production and industrial processes. The country's scramble to reduce its dependence on Russian gas has added further complexity to its ambitious aims to reduce carbon emissions over the coming decades. As a result, Berlin has further increased efforts to build closer ties with potential key exporters of hydrogen and derived products, including in the Middle East. German companies have also struck initial agreements for low-carbon fuels.



2MN T/YR

hydrogen from waste H2 Industries plan to produce by 2030

The UAE has emerged as a country of focus for Germany's ambitions to secure low-carbon supply. Both countries have repeatedly stressed their intention to collaborate closely across the hydrogen value chain and Abu Dhabi's state-owned Adnoc has entered into several agreements with German customers for demonstration cargoes of low-carbon ammonia. The first cargo was delivered in September to the port of Hamburg for Aurubis, a German provider of non-ferrous metals and one of the largest recycling firms for copper worldwide.

But supply deals for German companies have not been restricted to the UAE. Utility Uniper will offtake around 330,000 t/yr of green ammonia from a planned complex in Oman's Duqm port area that is developed by a joint venture between Omani state-owned OQ and Belgian engineering firm Deme. And Germany could become a key recipient of ammonia output from Saudi-Arabia's giant Neom project. Germany's economy ministry

said in November that a newly-announced ammonia import terminal in Hamburg — to be developed by industrial gas firm Air Products and energy trading company Mabana — will receive green ammonia from Saudi-Arabia "which Air Products produces locally". Air Products will be the sole offtaker of ammonia from the Neom facility, which is expected to produce around 1.2mn t/yr of green ammonia from 2026 onwards, utilising 2GW of electrolyser capacity.

Germany could also receive low-carbon hydrogen that is produced in the Middle East through less conventional routes. The German government in June agreed to facilitate imports of hydrogen made from organic waste in the Middle East and north Africa (Mena) region, according to US firm H2 Industries which is developing waste-to-hydrogen projects. H2 Industries has established a thermolysis process, where plastic and other organic waste are converted at high temperatures into hydrogen and by-product CO₂. The firm m plans to produce 2mn t/yr of hydrogen from waste in the region by 2030, having announced plans for facilities in Egypt and Oman. The firm in November struck an initial deal through which Egyptian waste management company Green Planet for Sustainable Environmental Solutions will supply 4mn t/ yr of waste feedstock to H2 Industries' planned complex at the country's East Port Said industrial park next to the Mediterranean entrance of the Suez Canal.

Germany's government-backed H2Global initiative may provide an opportunity for developers of green hydrogen projects in the Mena region to secure further offtake. Through the initiative, hydrogen and derived products are to be bought from projects outside of Europe under long-term agreements and then sold to consumers within Europe via shorter-term deals, with government funds to cover the likely price differentials. The programme is intended to help facilitate hydrogen supply chains and spur project developments globally. H2Global in early December launched its first tender for delivery of green ammonia in 2024-33, which is to be followed by tenders for e-methanol and sustainable aviation fuels shortly after.



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Uniquely situated in the energy calendar and sitting between COP27 in Egypt and COP28 in the UAE, the World Utilities Congress will convene global energy leaders, policymakers, innovators, and industry professionals from across the power & water utilities value chain to discuss the major trends and challenges shaping the industry as utilities worldwide work to deliver secure, sustainable, and affordable energy.

Hosted by TAQA, the exhibition and congress will take place from 8-10 May 2023 at ADNEC in Abu Dhabi.

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